International Journal of Civil Engineering and Technology (IJCIET)
Volume 8, Issue 3, March 2017, pp. 262–272 Article ID: IJCIET_08_03_027
Available online at http://www.iaeme.com/IJCIET/issues.asp?JType=IJCIET&VType=8&IType=3
ISSN Print: 0976-6308 and ISSN Online: 0976-6316

© **IAEME** Publication **Scopus** Indexed

SUITABILITY OF PARTIAL REPLACEMENT OF SAND WITH LATERITE FROM MALABAR REGIONS OF INDIA IN STRUCTURAL CONCRETE

Biju Mathew
Research Scholar, School of Civil Engineering,
Karunya University, Coimbatore, India

Dr. C. Freeda Christy
Associte Professor, School of Civil Engineering,
Karunya University, Coimbatore, India

Dr. Benny Joseph
Principal, Vimal Jyothi Engineering College Chemperi, India

ABSTRACT

Integration of new material as a partial fine aggregate replacement in concrete production would be able to reduce the high dependency of concrete manufacturer on river sand supply that may lead to ecological imbalance when this natural material is used excessively. This paper presents a study conducted to determine the suitability of partial replacement of sand with laterite available in Malabar regions of India in structural concrete. This study deals with Finite Element modeling of laterite concrete beam with the help of ANSYS. The load-deflection behavior of laterite beams under flexure is found to be bilinear. The deflection of laterite beam is more than deflection of ordinary beam but within the limit. In the present investigation, the results obtained from ANSYS and experimental results are almost equal for the laterite beam. The result shows the concrete with laterite up to 30 % replacement of fine aggregate is used for structural concrete and savings of 25% in cost of fine aggregate.

Key words: Laterite, Concrete, Strength, Fine Aggregate, Modelling, Deflection

Cite this Article: Biju Mathew, Dr. C. Freeda Christy and Dr. Benny Joseph, Suitability of Partial Replacement of Sand with Laterite From Malabar Regions of India In Structural Concrete. *International Journal of Civil Engineering and Technology*, 8(3), 2017, pp. 252–261.
http://www.iaeme.com/IJCIET/issues.asp?JType=IJCIET&VType=8&IType=3

1. INTRODUCTION

1.1. GENERAL

The huge quantity of concrete is consumed by construction industry all over the world. In India, the conventional concrete is produced using natural sand from river beds as fine aggregate. Decreasing natural resources poses the environmental problem and hence government restriction on sand quarrying from river bed resulted in scarcity and significant increase in cost. Digging sand, from river bed in excess quantity will affect the natural environment. The deep pits dug in the river bed, affects the ground water level. Thus, there is an increasing need to source alternative locally-available materials that could serve as suitable replacement to sand as fine aggregate in concrete. The cost of river sand comes around 2200 per cubic meter in Kerala.

The use of abundantly available and cheap materials to replace normal aggregates in concrete for structural purposes would prove to be economical in developing nations provided a reliable design data base on concrete produced with such materials is established. One of such materials is laterite-a naturally occurring hard soil widely spread in the tropics and subtropics. This material has been satisfactorily used as a "fill" for foundation and as a base course for highway construction long back in Malabar regions of Kerala in India (1). This study investigates the suitability of laterite as fine aggregate in place of sand in structural concrete.

1.2. The availability of Laterite in Malabar regions

In Malabar region of Kerala, the laterite stone is commonly used for the construction purpose. There are several laterite stone quarries in Kannur region. During excavation of laterite stone, around 25 – 30 per cent laterite stone scrap is generated. It is estimated that about 2.83 cum of the laterite stone scrap is generated during excavation of about 11.33 cum of the laterite stone (2). This laterite stone scrap creates problem in quarries and needs removal for further excavation and use of this waste material in construction purpose. The objective of this project is to examine the Physical properties of M 25 concrete made with laterite available in Ulikkal, Kannur district as replacement of natural fine aggregate in concrete

Olubisi A. Ige (2013): in their investigation of weathering characteristics of Laterite concrete with laterite-fine aggregate ratio as a factor in operating weather conditions (wet and dry seasons) in tropics, including Nigeria for the mix proportion used was 1:2:4, The results showed that the compressive strength of laterite concrete with laterite-fine aggregate ratio variation decreases when subjected to alternate wetting and drying and increases when subjected to magnesium sulphate (Mg2SO4).

L. O. Ettu et al (2012) reported the suitability of laterite as sole fine aggregate in place of sand for making structural concrete suitable for use in communities with problematic soils that have poor bearing capacities.

K .Muthu Swamy and N.W. kamauzaman (2012), investigated the suitability of Malaysian laterite as a fine aggregate and found that up to 30 % replacement of laterite with sand can be used.

Biju Mathew, Dr C. Frreda Christy and Dr Benny Joseph studies the strength characteristics of laterite available in Malabar region with replacement of fine aggregate (Natural sand) in concrete and showed that up to 20 % of replacement of sand with laterite without use of superplastizer can be used for concrete purpose.

2. EXPERIMENTAL INVESTIGATION

The aim of the present investigation was to experimentally study the behaviour of laterite concrete using laterite as fine aggregate from Malabar regions of Kerala. In this study 30% replacement of natural sand by laterite was adopted. Thus a total of 6 beams and 6 control specimens were tested. RC beam specimens with and without laterite were prepared to compare the effect of addition of laterite in reinforced concrete. Two series of beams of size 700mm×150mm×150mm were used for the present study. Each series consisted of three beams. Compressive strength was also studied for the present investigation.

2.1. MATERIAL PROPERTIES

The properties of cement, fine aggregate, coarse aggregate and water used in the concrete mix as per procedures and recommended value specified by the respective IS codes.

2.1.1. Mix proportion

The mixes were designed as per IS 10262:1982 based on the properties of ingredients for M25 Concrete. The mix proportions for two grades of concrete are shown in Table 1.

Table 1 Concrete Mix Proportions

Grade of concrete	**Mix proportion**					
	C	**FA**	**LFA**	**CA**	**W**	**SP**
M25	1	1.12	0	2.61	0.43	.006
M25	1	0.78	0.34	2.61	0.43	.006

2.1.2. Reinforcement

HYSD bars of diameter 8mm were used as main reinforcement and two legged 8mmΦ stirrups at 216mm c/c spacing were used as shear reinforcement.

2.2. TEST SPECIMEN

A conventional rotary concrete mixer machine was used to mix the concrete. The structural specimen having the size of 700 mm X 150 mm X 150 mm was used with reinforcement. Standard cube of size 150 mmx150 mm x150 mm were casted for studying the compressive strength. All beam specimen and cubes casted were demoulded after 24 hours of casting and immersed in water for curing up to 28 days.

The beams were designed as under-reinforced sections as per IS 456:2000 stipulations. All the beams have the same dimensions of overall length 700mm with effective span of 600mm. The cross sectional area of the beam is 150mm×150mm with an effective depth of 125mm. The clear cover provided was 25mm. Two 8mmΦ HYSD bars of Fe415 grade were provided at bottom as tension reinforcement and two 8mmΦ HYSD bars of Fe415 grade at top as stirrup holders. Two legged 8mmΦ stirrups at a spacing of 216mm c/c were provided as shear reinforcement. The details of the reinforcement provided are shown in Fig. 1

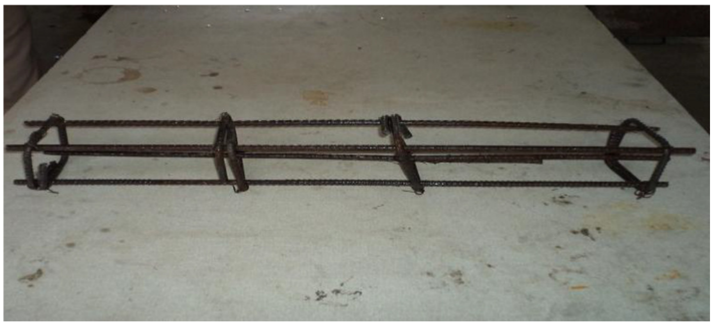

Figure 1 Reinforcement Configuration

4.6. TESTING OF SPECIMENS

The cube compressive strength of laterite concrete and ordinary concrete was tested in compression testing machine for each series of beams. The size of test beams is 700mm Length, 150 mm Breadth and 150 mm depth. The effective span length is 600 mm. Dimensions and loading details are shown in Fig-2. The beam was placed for testing in universal testing machine having 1000 KN capacity. A constant load of (approximately about 10% of the capacity of the beam) was applied to hold the specimen in position and to simulate the load. A deflecto meter with least count of 0.01 mm was installed exactly at the center of the beam to measure the maximum deflection at the bottom. The loading was given gradually at the top of the beam. Loading and corresponding deflections were observed and recorded. The safe values among three specimens had been taken for comparison.

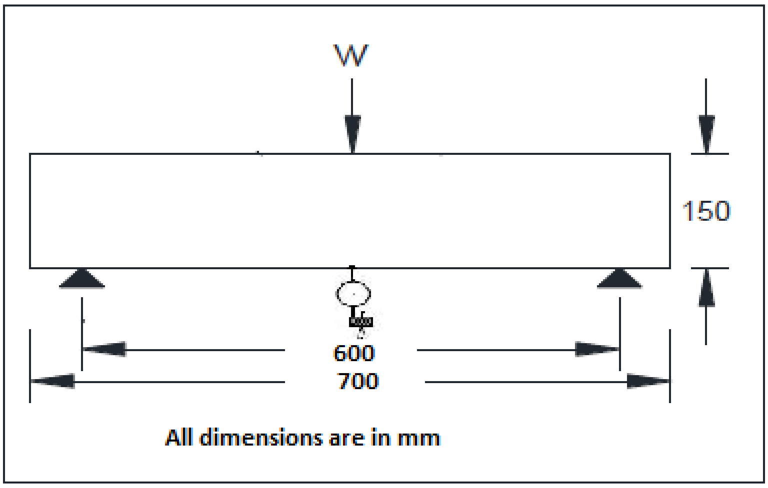

Figure 2 Schematic Diagram of Flexure Test

3. ANALYSIS OF TEST RESULTS

The cube specimens were tested for cube compressive strength. The behaviour of laterised reinforced concrete and ordinary concrete was studied under static loading. The parameters considered under static loading were deflection, crack pattern, first cracking load and ultimate load carrying capacity. From the load-deflection graphs, pre-cracking stiffness and post-cracking stiffness were studied.

3.1. PROPERTIES OF HARDENED CONCRETE

The cube compressive strength of laterite concrete and ordinary concrete obtained by testing the control specimens for each series of beams is shown in Table 2.

Table 2 Average Cube Compressive strength

Series	f_{28} (N/mm^2)
LCC	36.6
CC	39.55

3.1.1. Load-Deflection Characteristics

The Load Vs Deflection graph at mid span of two beams is shown in Fig.3. From the graph, it is observed that the Load Vs Deflection graph is bilinear for beams. After the first crack, the deflection is seen to increases.

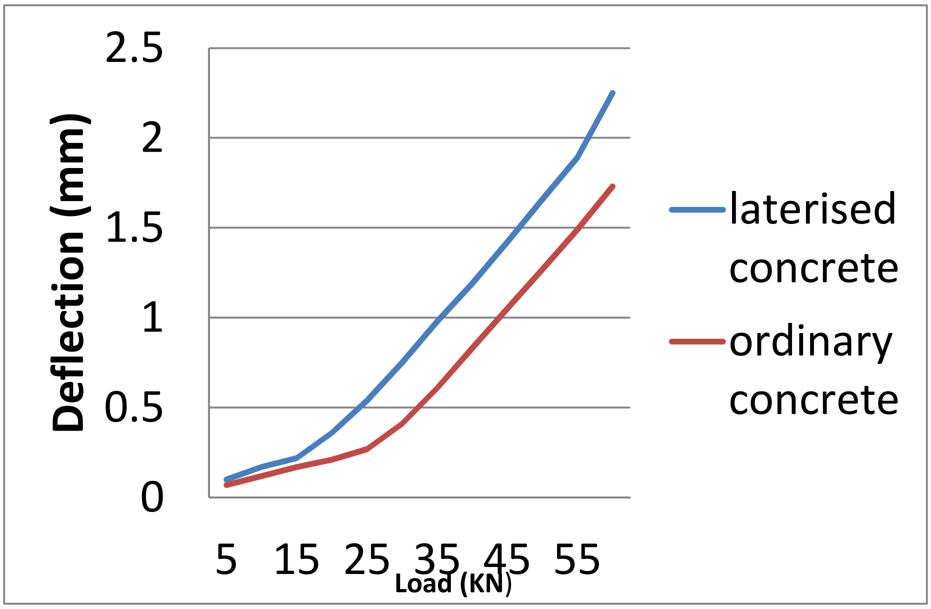

Figure 3 Load Vs deflection graph

3.1.2. Cracking Load and Ultimate Load

The load for first crack observed and the ultimate load are shown in Table 3. It is seen that the load at first crack and ultimate load slightly decrease for laterite concrete

Table 3 First Crack Load and Ultimate Load of Beam Specimens

Type	**Load at first crack P_{cra} (kN)**	**Ultimate Load P_u (kN)**	P_u/P_{cra}
Ordinary concrete	40	79	1.75
Laterite concrete	30	73	2.43

Replacement of 30 % laterite in fine aggregate results only a marginal decrease in the ultimate load. The average decrease in ultimate load for laterite concrete beams is 7.5% than that of ordinary beams.

The theoretical ultimate load was found out by IS method is 66.5KN. Ultimate load obtained experimentally shows that failure load is higher than corresponding theoretical load in laterite concrete beams.

3.1.3. Crack Pattern

The cracks formed on the beam specimens when loaded were marked. The crack patterns of beams are shown in Fig.4 and 5. From the study, it is seen that the number of cracks formed for both ordinary and laterite beams were same. But the rate of crack propagation for laterite beams is found to be faster than that for ordinary beams.

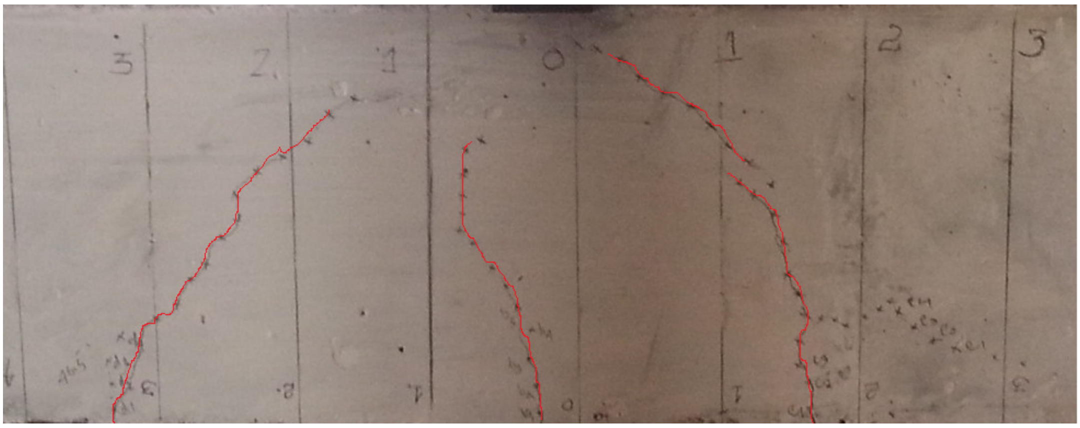

Figure 4 Crack Pattern of Beam under Flexure of ordinary Beam

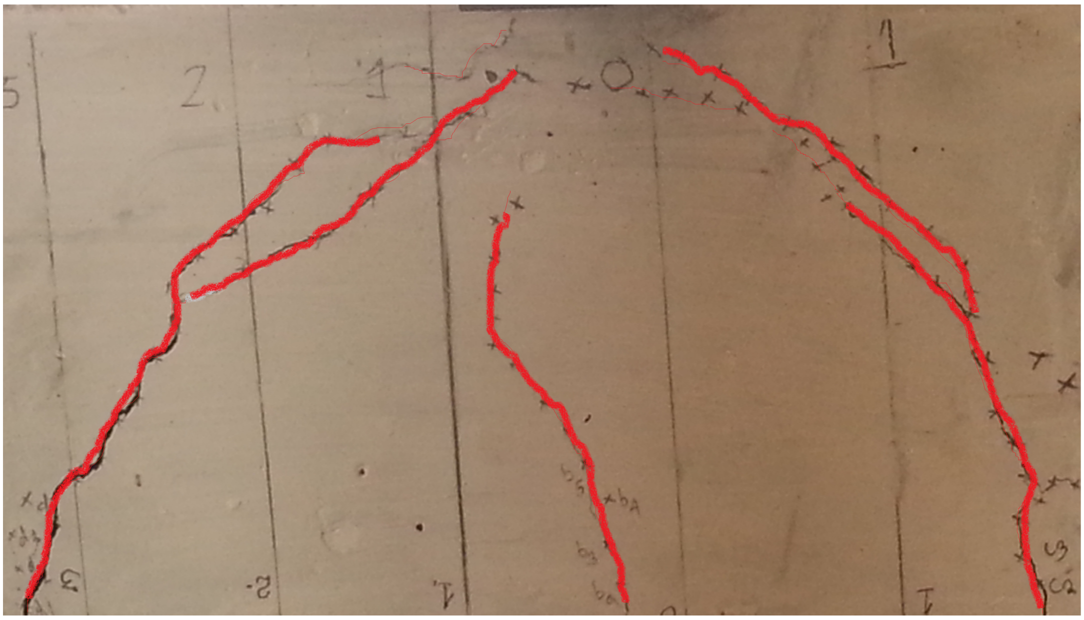

Figure 5 Crack Pattern of Beam under Flexure with Laterite

As per clause 23.2.(a) of IS 456: 2000, the deflection produced in the beams subjected to flexure should not exceed *l*/250 (2.8mm for the specimens tested in the present investigation) in their service life. From the experiment, it is noted that for all the beams tested, the stipulated 2.8mm deflection was not at all reached.

4. ANALYTICAL STUDIES

The basic concept of FEM modeling is the subdivision of the mathematical model into disjoint (non-overlapping) components of simple geometry. The response of each element is expressed in terms of a finite number of degrees of freedom characterized as the value of an unknown function, or functions or at a set of nodal points. The response of the mathematical model is then considered to be the discrete model obtained by connecting or assembling the collection

of all elements. Depending on the type of material modeling to be solved in ANSYS, concrete can be represented by solid block.

4.1. CONCRETE MODELLING

4.1.1. Behavior of the Concrete

Concrete exhibits a large number of micro cracks, especially, at the interface between coarser aggregates and mortar, even before subjected to any load. The presence of these micro cracks has a great effect on the mechanical behavior of concrete, since their propagation during loading contributes to the nonlinear behavior at low stress levels and causes volume expansion near failure. Many of these micro cracks are caused by segregation, shrinkage or thermal expansion of the mortar. Some micro cracks may develop during loading because of the difference in stiffness between aggregates and mortar. Since the aggregate-mortar interface has a significantly lower tensile strength than mortar, it constitutes the weakest link in the composite system. This is the primary reason for the low tensile strength of concrete. The response of a structure under load depends to a large extent on the stress-strain relation of the constituent materials and the magnitude of stress. Since concrete is used mostly in compression, the stress-strain relation in compression is of primary interest.

4.1.2. Geometry of the Concrete

Element geometric modeling of concrete has been done using 3D solid block element with 8 up to 20 nodes.

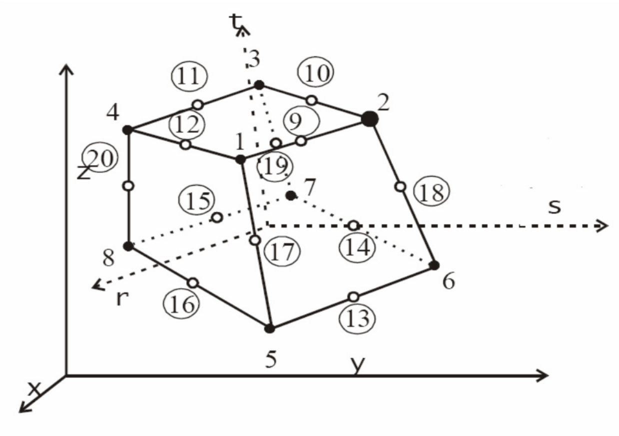

Figure 7 Element Model

4.1.3. Element Properties

3D solid brick element having three degree of freedom at each node: translations in the nodal x, y and z directions. This is an iso parametric element integrated by Gauss integration at integration points. This element is capable of plastic deformation, cracking in three orthogonal directions, and crushing. The most important aspect of this element is the treatment of nonlinear material properties

4.1.4. Element Interpolation function

3D solid brick element interpolation functions for all variants of the elements are given below:

N1= (1/8) (1+r) (1+s) (1+t) N2= (1/8) (1-r) (1+s) (1+t)

N3= (1/8) (1-r) (1-s) (1+t) N4= (1/8) (1+r) (1-s) (1+t)

N5= (1/8) (1+r) (1+s) (1-t) N6= (1/8) (1-r) (1+s) (1-t)

N7= (1/8) (1-r) (1-s) (1-t) N8= (1/8) (1+r) (1-s) (1-t)

4.2. STATIC ANALYSIS

4.2.1. Steps included in analysis are

1. Problem Specification
2. Problem Description
3. Build Geometry
4. Define material
5. Generate mesh
6. Apply Loads
7. Obtain solution
8. Review Results

4.2.2. Problem Specification

Applicable ANSYS products: ANSYS STRUCTURAL

Level of Difficulty: Moderate

Interactive time required: 30 to 40 min

Element Type used: Solid, Concrete 65

Analysis type: Linear Elastic

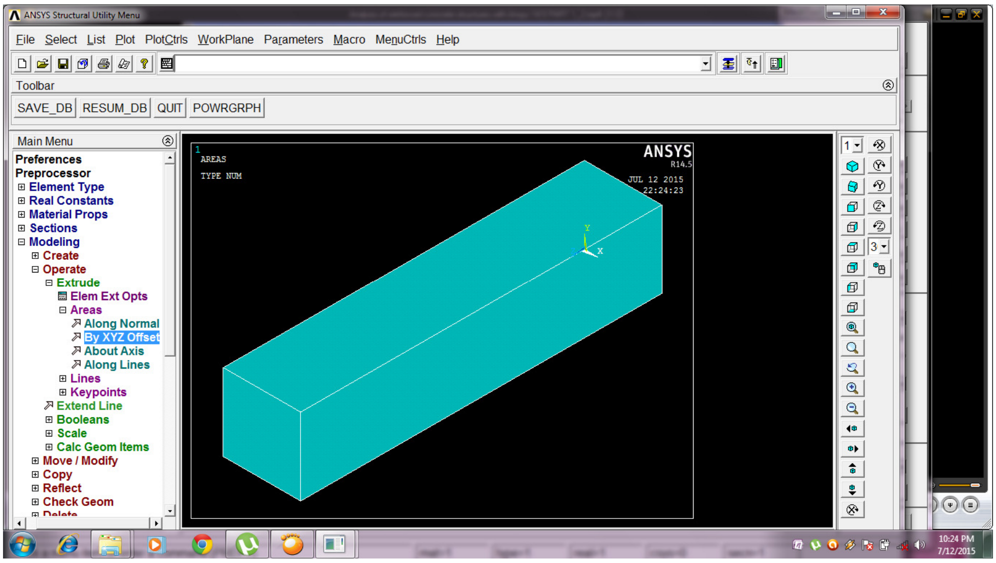

Figure 8 Building Geometry

Building geometry includes, giving the dimensions and modeling the beam as a solid block. After building the geometry, the concrete properties such as compressive strength, poison's ratio, modulus of elasticity, density are assigned to the model. The reinforcement details are also assigned and the model is meshed.

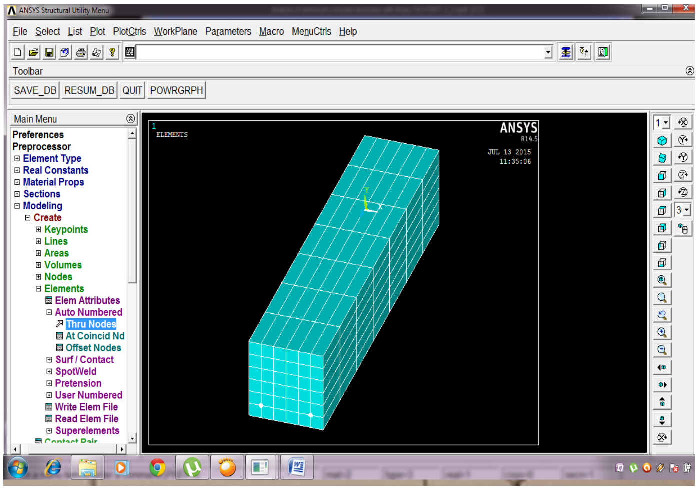

Figure 10 Meshing the model

After meshing the model using the mesh tool, load points and support points were assigned and linear elastic analysis was done. From the analysis, the deflection at mid span of all the six beams is obtained. The deformed shape of the beams is as shown

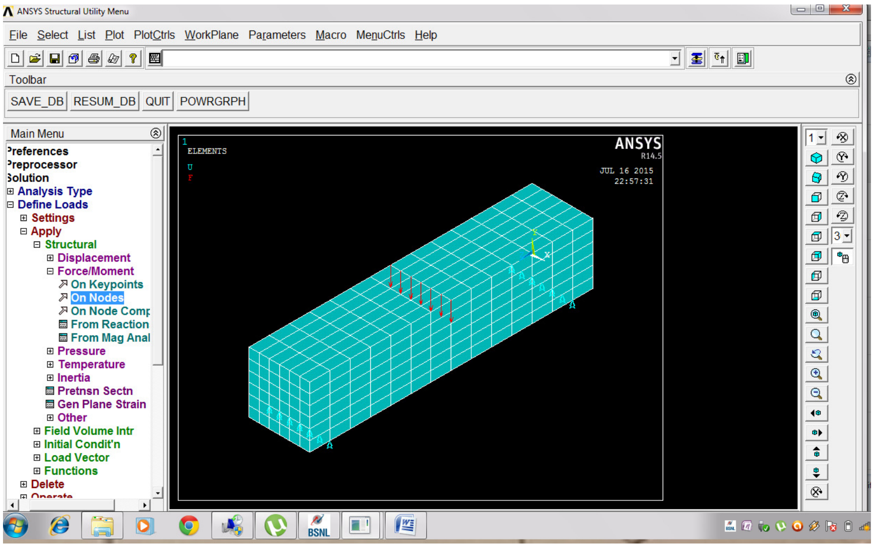

Figure 10 Applying Load

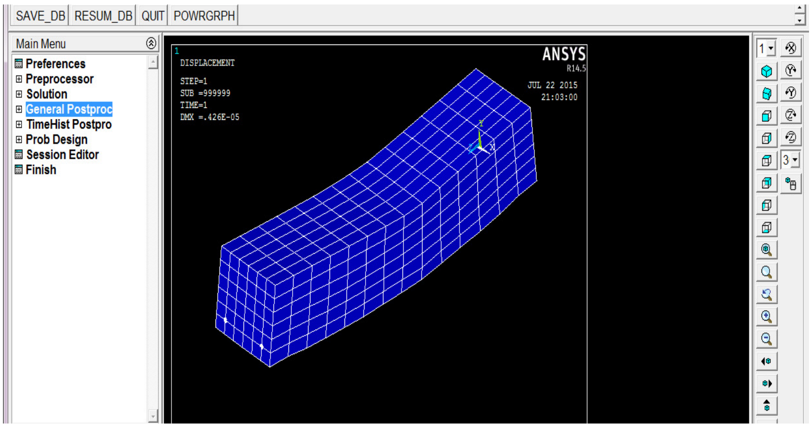

Figure 11 Deformed shape of the beam

4.3. Comparison of the analytical and experimental results

From the results it is evident that, the analytical results are almost nearer to that of the experimental values. The slight difference may be due to the fact that accurate modelling of the support and load condition was not possible in practical.

Table 4 Comparison of results

Load (kN)	Experimental Deformation (mm)	ANSYS results Deformation (mm)
5	.1	.14
10	0.17	0.21
15	0.22	0.26
20	0.36	0.39
25	0.54	0.59
30	0.75	0.81

In the present investigation, the results obtained from ANSYS and experimental results are almost equal for the laterite beams. ANSYS modeling of RCC structures can be done instead of going for the expensive and time consuming experimental procedures.

5. CONCLUSION

From the present experimental investigation the following conclusions are arrived at:

- The replacement fine aggregate by laterite is found to decrease 28^{th} day compressive strength.
- The load-deflection behaviour of laterite beams under flexure is found to be bilinear.
- Deflection of laterite beam is more than deflection of ordinary beam but within the limit
- ANSYS modeling of RCC structures can be done instead of going for the expensive and time consuming experimental procedures.
- In the present investigation, the results obtained from ANSYS and experimental results are almost equal for the laterite beam.
- Hence it is recommended for structural concrete up to 30 % replacement of fine aggregate with laterite and can save 25% in cost of fine aggregate.

REFERANCES

[1] Thomas Varghese and Byju G., (1993), Laterite soils, their distribution, characteristics classification and management, Published by State Committee on Science, Technology and Environment, Government of Kerala, Thiruvananthapuram

[2] S.K. Jain, P.G. Patil, N.J. Thakor, Engineering properties of laterite stone scrap blocks, Agricultural Engineering International: CIGR Journal. Vol.13, No.3, 2011. No.1738.

[3] K.Muthusamy and N.W.Kamaruzamanm, Assessment of Malaysian Laterite Aggregate in Concrete, International Journal of Civil & Environmental Engineering Vol:12 No:04 PP 83-86, ISSN:1213804-5757

[4] Wikipedia, 2012, about lateritic soil. < http://en.wikipedia.org/wiki/ Laterite >, 20'th July 2012.

[5] Wikipedia, 2012 b, About lateritic formation in Karnataka .< http://en.wikipedia.org/wiki/ Geography _of_ Karnataka

[6] IS: 456-2000, Plain and Reinforced Concrete- Code of Practice, Bureau of Indian Standards, New Delhi, 2000.

[7] IS: 383-1970, Indian standard specification for coarse and fine aggregate from natural sources for concrete, Bureau of Indian Standards, New Delhi, India.

[8] IS: 9103-1999, Indian standard concrete admixtures -specification, Bureau of Indian Standards, New Delhi, India.

[9] IS: 516-1959, Indian standard methods of test for strength of concrete, Bureau of Indian Standards, New Delhi, India

[10] IS: 10262-2009, Indian standard recommended guidelines for concrete mix design, Bureau of Indian standards, New Delhi.

[11] Shetty M.S. Concrete Technology - Theory and Practice, S. Chand & Company P. Ltd., New Delhi, 2005.

[12] Neville, A.M., (1981). Properties of Concrete, Pitman publishing LTD, London

[13] Biju Mathew ,Dr C Freeda Christy , Dr Benny Joseph , Tensile Strength characteristic of Concrete using Laterite as Fine aggregate, International journal of Social Science and Interdisciplinary Research Vol:4 No.4,PP-76-83 April 2015, ISSN 2277-3630.

[14] Biju Mathew ,Dr C Freeda Christy , Dr Benny Joseph , Strength performance of concrete using Laterite as sand replacement , International journal of civil engineering research and application Vol:1 No.3,PP-38-42 ,August 2013

[15] Biju Mathew ,Dr Freeda Christy C, Dr Benny Joseph, An experimental study on properties of cement mortar by replacement of natural sand with manufactured sand . International journal of Civil engineering & technology (IJCIET), Vol: 7, no 4, PP 483-490, July 2016.

[16] Biju Mathew, Madhu T.K, Dr Benny Joseph, An experimental study on effect of short fiber reinforcement in laterized concrete. International journal of Civil engineering & technology (IJCIET), Vol: 7, no 4, PP 393-399, July 2016.